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UNITED STATES PATENT APPLICATION FOR

CONTROLLABLE PIXEL BORDER FOR  
A NEGATIVE MODE PASSIVE  
MATRIX DISPLAY DEVICE

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CONTROLLABLE PIXEL BORDER FOR  
A NEGATIVE MODE PASSIVE  
MATRIX DISPLAY DEVICE

5 BACKGROUND OF THE INVENTION

RELATED US APPLICATION

The present application is a continuation-in-part application of co-pending US application, serial number, 09/709,142, by Canova, et al., entitled "Pixel Border for Improved Viewability of a Display Device," filed November 8, 2000 and  
10 which is hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to the field of display screen technology. More specifically, embodiments of the present invention relate to flat panel  
15 display screens that are useful in conjunction with portable electronic devices.

RELATED ART

As the components required to build a computer system have reduced in size, new categories of computer systems have emerged. One of the new  
20 categories of computer systems is the "palmtop" computer system. A palmtop computer system is a computer that is small enough to be held in the hand of a user and can therefore be "palm-sized." Most palmtop computer systems are used to implement various Personal Information Management (PIM) applications such as an address book, a daily organizer and electronic notepads, to name a few. Palmtop computers with PIM software have been known as Personal Digital  
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Assistants (PDAs). Many PDAs have a small flat display screen associated therewith.

In addition to PDAs, small flat display screens have also been

5 implemented within other portable electronic devices, such as cell phones, electronic pagers, remote control devices and other wireless portable devices.

Liquid crystal display (LCD) technology, as well as other flat panel display technologies, have been used to implement many of the small flat display

10 screens used in portable electronic devices. These display screens contain a matrix of pixels, with each pixel containing subpixels for color displays. Some of the displays, e.g., color displays, use a back lighting element for projecting light through an LCD matrix. Other displays, e.g., black and white, use light reflectivity to create images through the LCD matrix and these displays do not need back

15 lighting elements when used in lit surroundings. Whether color or in black and white, because the displays used in portable electronic devices are relatively small in area, every pixel is typically needed and used by the operating system in order to create displays and present information to the user. Additionally, because the display device is typically integrated together with the other

20 elements of the portable electronic device, the operating systems of the portable electronic devices typically expect the display unit to have a standard pixel dimension, e.g., a standard array of ( $m \times n$ ) pixels is expected.

Figure 1A illustrates a typical black and white display screen having a

25 standard size pixel matrix 20 with an exemplary edge-displayed character

thereon. The edge-displayed character is the letter "A" and is displayed at the left hand side of the display screen at an arbitrary height. The technology could be either transmissive, transflective or reflective passive matrix display, e.g., liquid crystal display (LCD). In a conventional black and white display screen, the  
5 background pixels 26 can be light, e.g., not very dark, and the pixels 24 that make up the edge-displayed character can be dark. Importantly, in a positive mode display LCD, unless driven on, the pixels are white. Therefore, the edge location 28 of the display screen, e.g., between the edge of the matrix 20 and the bezel 22 of the portable electronic device, is typically white. As a result, the left edge of the  
10 edge-displayed character, "A," has good contrast and is therefore easily viewed by the user. This is the case regardless of the particular edge used, e.g., left, right, top, bottom, because region 28 surrounds the matrix 20.

Figure 1B illustrates a typical display screen having a pixel matrix 20' with  
15 the same edge-displayed character thereon but using negative mode display LCD technology. In negative mode display LCD, unless driven on, the pixels are black. The edge-displayed character is the letter "A" and is displayed at the left hand side of the display screen at an arbitrary height. In this format, the background pixels 26 can still be light and the pixels 24 that make up the edge-  
20 displayed character can still be dark. However, importantly, the edge location 28 of the display screen, e.g., between the edge of the matrix 20' and the bezel 22 of the portable electronic device, is typically dark in negative mode display LCD. Being dark, the edge region 28 is the same or similar color as the pixels 24 that make up the character. Therefore, the left edge of the edge-displayed character,  
25 "A," has very poor contrast and is therefore typically lost as illustrated in Figure

1B. This makes reading the edge displayed character very difficult for a user. This is the case regardless of the particular edge used, e.g., left, right, top, bottom, because region 28 surrounds the matrix 20'.

5        In an attempt to address this problem, some computer systems do not display edge-located characters to avoid the contrast problems associated with the screen edge. Many desktop computer systems, for example, simply try to avoid the display of edge-located characters on the cathode ray tube (CRT) screen or on a large flat panel display. However, this solution is not acceptable in

10      the case of a small display screen where every pixel is needed for image and information presentation. What is needed is a display that makes maximal use of the available screen pixels while eliminating the problems associated with edge displayed characters in a display format where the pixels of the character are of the same or similar color as the edge region 28. What is also needed is a

15      solution that is also compatible with standard display screen dimensions, formats and driver circuitry.

## SUMMARY OF THE INVENTION

Accordingly, embodiments of the present invention provide an electronic device, e.g., a cell phone, portable computer system, PDA, electronic pager, etc., having a screen that makes maximal use of the available screen pixels while

5       eliminating the problems associated with edge displayed characters in display formats where the pixels of the character are of the same or similar color as the edge region. Embodiments of the present invention are particularly useful in negative mode passive matrix LCD displays that utilize a brighter background and a darker foreground. Embodiments provide the above benefits while being

10     compatible with standard display screen dimensions, formats and driver circuitry. Embodiments of the present invention therefore provide a small display screen with improved viewability, especially at the edge locations. The present invention provides these advantages and others not specifically mentioned above but described in the sections to follow.

15           A display device is described herein having a display matrix including a pixel border of width  $x$  and located around the edge locations of the matrix for improved viewability. In particular, the border region can be several pixels wide, e.g.,  $1 < x < 5$ . In one embodiment, the border region is two pixels wide and

20     surrounds a display region in which images are generated from a frame buffer memory. In one implementation, both the border region and the display region are implemented using a negative display mode passive display matrix using supertwisted nematic liquid crystal display (LCD) technology. Other passive matrix techniques could also be used in addition to LCD technology, such as,

electronic paper, electronic ink, or microelectromechanical machine systems (MEMS), etc.

In one embodiment, the pixels of the border region are controllable

5 between an on state and an off state and have an adjustable threshold voltage level. The threshold voltage level can originate from a gray scale bias circuit which can be controlled by a contrast adjustment. This allows the border brightness and the background brightness to be matched in response to contrast adjustments. In one embodiment, the display screen is a negative mode display

10 in which the pixels are normally black when off. The pixel border is useful in providing contrast in display modes having a white background with black characters displayed therein. In these display modes, the border region is uniformly turned on to provide a white border. As discussed above, the white border adjusts with the background brightness in response to contrast

15 adjustments. The present invention can be applied in either monochrome or color displays. The pixel border is also advantageous in that it can be used with conventional character generation processes of the operating system of the computer used to drive the display screen. In one embodiment, the novel display can be used within a portable computer system or other portable electronic

20 device.

More specifically, an embodiment of the present invention includes a display unit (and a computer system including the display unit) comprising: a passive matrix of independently controllable pixels comprising n rows and m columns of discrete pixels, the passive matrix operable to generate an image in

response to electronic signals driven from row and column drivers coupled to the passive matrix, the image representative of information stored in a frame buffer memory; and a pixel border having a predetermined width, the pixel border surrounding the passive matrix and comprising a plurality of pixels which are

5 uniformly controlled between an on and an off state by a common threshold signal.

Embodiments of the present invention include the above and further comprising: a contrast adjustment circuit for adjusting voltage levels supplied to the row and column drivers to adjust the contrast of the image of the passive matrix, and wherein the contrast adjustment circuit is also operable to adjust the common threshold signal to match the contrast of the pixel border to that of the passive matrix. In one implementation the image has a white background and a black foreground and wherein the pixel border is driven to the on state to be white

10 to match the background. Embodiments include the above and wherein the passive matrix is negative display mode supertwisted nematic liquid crystal display technology.

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Embodiments include the above and wherein the passive matrix is electronic ink technology or microelectromechanical system (MEMS) technology.

20 Embodiments include the above and further comprising a drive circuit responsive to a single control signal for generating the common threshold signal.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A illustrates a display screen of the prior art having an edge displayed character where the background pixels are light and the character is composed of darker pixels.

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Figure 1B illustrates a display screen of the prior art having an edge displayed character in a video format where the pixels of the character are of the same or similar color and shade as the edge region of the display panel.

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Figure 2A is a top side perspective view of an exemplary palmtop computer system that can be used in one embodiment of the present invention.

Figure 2B is a bottom side perspective view of the exemplary palmtop computer system of Figure 2A.

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Figure 2C is another exemplary computer system embodiment

Figure 3 is a logical block diagram of the exemplary palmtop computer system in accordance with an embodiment of the present invention.

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Figure 4 is a front view of the exemplary computer system that can be used within the display screen of the present invention.

25 Figure 5 is an exemplary communication network in which the exemplary palmtop computer can be used.

Figure 6 is a perspective view of a cradle device for connecting the exemplary palmtop computer system to other systems via a communication interface.

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Figure 7 illustrates a display screen in accordance with one embodiment of the present invention including a controllable border pixel region and a frame buffer pixel region using a passive matrix display.

10       Figure 8 is a block diagram of the display unit in accordance with one embodiment of the present invention.

15       Figure 9 is a logical block diagram of the display driver circuitry and passive matrix structure, with controllable pixel border regions, in accordance with an embodiment of the present invention.

20       Figure 10 illustrates the components of a color pixel of the passive matrix structure in accordance with one embodiment of the present invention.

25       Figure 11 is a voltage transfer case of the passive matrix structure in accordance with one embodiment of the present invention.

Figure 12 is a logical block diagram of the display in accordance with one embodiment of the present invention having an adjustable threshold voltage applied to the controllable pixel border regions.

Figure 13A is a cross sectional view of a backlit display matrix including a cross sectional view of the passive matrix controllable pixel border region in accordance with an embodiment of the present invention.

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Figure 13B is a cross sectional view of a reflective display matrix including a cross sectional view of the passive matrix controllable pixel border region in accordance with an embodiment of the present invention.

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Figure 14 is an exemplary display using the display unit with controllable pixel border in accordance with one embodiment of the present invention and having a negative mode passive matrix display.

### DETAILED DESCRIPTION OF THE INVENTION

In the following detailed description of the present invention, a controllable pixel border for a negative display mode passive matrix display screen which provides contrast improvement for increased viewability of edge-displayed characters, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be recognized by one skilled in the art that the present invention may be practiced without these specific details or with equivalents thereof. In other instances, well known methods, procedures, components, and circuits have not been described in detail as not to unnecessarily obscure aspects of the present invention.

The following co-pending application is hereby incorporated by reference, serial number, 09/709,142, by Canova, et al., entitled "Pixel Border for Improved Viewability of a Display Device," filed November 8, 2000 and assigned to the assignee of the present invention.

### EXEMPLARY PORTABLE ELECTRONIC DEVICE PLATFORM

Although the display screen of the present invention can be implemented in a variety of different electronic systems such as a pager, a cell phone, a remote control device, etc., one exemplary embodiment includes the integration of the display screen with a portable electronic device.

Figure 2A is a perspective illustration of the top face 100a of one embodiment of a palmtop computer system that can be used in one implementation of the present invention. The top face 110a contains the novel

display screen 105 surrounded by a bezel or cover. A removable stylus 80 is also shown. The novel display screen 105 contains a transparent touch screen (digitizer) able to register contact between the screen and the tip of the stylus 80. The novel display screen 105 is described in more detail further below. The  
5 stylus 80 can be of any material to make contact with the screen 105. As shown in Figure 2A, the stylus 80 is inserted into a receiving slot or rail 350. Slot or rail 350 acts to hold the stylus when the computer system 100a is not in use. Slot or rail 350 may contain switching devices for automatically powering down and automatically power up computer system 100a based on the position of the stylus  
10 80. The top face 100a also contains one or more dedicated and/or programmable buttons 75 for selecting information and causing the computer system to implement functions. The on/off button 95 is also shown.

Figure 2A also illustrates a handwriting recognition pad or "digitizer" containing two regions 106a and 106b. Region 106a is for the drawing of alpha characters therein for automatic recognition (and generally not used for recognizing numeric characters) and region 106b is for the drawing of numeric characters therein for automatic recognition (and generally not used for recognizing numeric characters). The stylus 80 is used for stroking a character  
15 within one of the regions 106a and 106b. The stroke information is then fed to an internal processor for automatic character recognition. Once characters are recognized, they are typically displayed on the screen 105 for verification and/or modification.  
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The digitizer 160 records both the (x, y) coordinate value of the current location of the stylus and also simultaneously records the pressure that the stylus exerts on the face of the digitizer pad. The coordinate values (spatial information) and pressure data are then output on separate channels for sampling by the 5 processor 101 (Figure 3). In one implementation, there are roughly 256 different discrete levels of pressure that can be detected by the digitizer 106. Since the digitizer's channels are sampled serially by the processor, the stroke spatial data are sampled "pseudo" simultaneously with the associated pressure data. The sampled data is then stored in a memory by the processor 101 (Figure 3) for later 10 analysis.

Figure 2B illustrates the bottom side 100b of one embodiment of the palmtop computer system. An optional extendible antenna 85 is shown and also a battery storage compartment door 90 is shown. A communication interface 108 is also shown. In one embodiment of the present invention, the serial 15 communication interface 108 is a serial communication port, but could also alternatively be of any of a number of well known communication standards and protocols, e.g., parallel, SCSI, Firewire (IEEE 1394), Ethernet, etc. In Figure 2B is also shown the stylus receiving slot or rail 350.

20 Figure 2C illustrates a front perspective view of another implementation of the palmtop computer system 100c. As shown, the flat central area is composed of the novel display screen area 105 and a thin silk screen layer material portion 84. Typically, the silk screen layer material portion 84 is opaque and may contain 25 icons, buttons, images, etc., graphically printed thereon in addition to regions

106a and 106b. The novel display screen area 105 and portion 84 are disposed over a digitizer.

Figure 3 illustrates circuitry of portable computer system 100. Computer  
5 system 100 includes an address/data bus 99 for communicating information, a central processor 101 coupled with the bus 99 for processing information and instructions, a volatile memory 102 (e.g., random access memory RAM) coupled with the bus 99 for storing information and instructions for the central processor 101 and a non-volatile memory 103 (e.g., read only memory ROM) coupled with  
10 the bus 99 for storing static information and instructions for the processor 101. Computer system 110 also includes an optional data storage device 104 (e.g., thin profile removable memory) coupled with the bus 99 for storing information and instructions. Device 104 can be removable. As described above, system 100 also contains a display device 105 coupled to the bus 99 for displaying  
15 information to the computer user.

Also included in computer system 100 of Figure 3 is an alphanumeric input device 106 which in one implementation is a handwriting recognition pad ("digitizer") having regions 106a and 106b (Figure 2A), for instance. Device  
20 106 can communicate information (spatial data and pressure data) and command selections to the central processor 101.

System 110 also includes an optional cursor control or directing device 107 coupled to the bus for communicating user input information and command  
25 selections to the central processor 101. In one implementation, device 107 is a

touch screen device (also a digitizer) incorporated with screen 105. Device 107 is capable of registering a position on the screen 105 where the stylus makes contact and the pressure of the contact. The digitizer can be implemented using well known devices, for instance, using the ADS-7846 device by Burr-Brown 5 that provides separate channels for spatial stroke information and pressure information.

The display device 105 utilized with the computer system 100 may be a liquid crystal device, cathode ray tube (CRT), field emission device (FED, also 10 called flat panel CRT) or other display device suitable for creating graphic images and alphanumeric characters recognizable to the user. Any of a number of display technologies can be used, e.g., LCD, FED, plasma, etc., for the flat panel display 105. In one embodiment, the display 105 is a flat panel multi-mode display capable of both monochrome and color display modes.

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Signal communication device 108, also coupled to bus 99, can be a serial port (or USB port) for communicating with the cradle 60. In addition to device 108, wireless communication links can be established between the device 100 and a host computer system (or another portable computer system) 20 using a Bluetooth wireless device 360, an infrared device 355, or a GSM radio device 240. Device 100 may also include a wireless modem device 240 and/or a wireless radio, e.g., a GSM wireless radio with supporting chipset. The wireless modem device 240 is coupled to communicate with the processor 101 but may not be directly coupled to port 108.

In one implementation, the Mobitex wireless communication system may be used to provide two way communication between system 100 and other networked computers and/or the Internet via a proxy server. In other 5 embodiments, TCP protocol can be used or SMS can be used. System 100 of Figure 4 may also contain batteries for providing electrical power. Replaceable cells or rechargeable batteries can be used. Well known electronics may be coupled to the battery to detect its energy level and this information can be sampled by the processor 101.

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Figure 4 is a front view of the exemplary palmtop computer system 100 having an exemplary display within screen 105. The exemplary display contains one or more graphical user interface elements including a menu bar and selectable on-screen buttons 410. Buttons on screen 105 can be selected by the 15 user directly tapping on the screen location of the button with stylus 80 as is well known. Also shown are two regions of digitizer 106a and 106b. Region 106a is for receiving user stroke data (and pressure data) for alphabet characters, and typically not numeric characters, and region 106b is for receiving user stroke data (and pressure data) for numeric data, and typically not for alphabetic characters. 20 Physical buttons 75 are also shown. Although different regions are shown for alphabetic and numeric characters, the device is also operable within a single region that recognizes both alphabetic and numeric characters.

It is appreciated that, in one embodiment, the digitizer region 106a and 106b are separate from the display screen 105 and therefore does not consume any display area.

5       Figure 5 illustrates a communication system 50 that can be used in conjunction with the palmtop computer system 100. System 50 is exemplary and comprises a host computer system 56 which can either be a desktop unit as shown, or, alternatively, can be a laptop system 58. Optionally, one or more host computer systems can be used within system 50. Host computer systems 58 and  
10 56 are shown connected to a communication bus 54, which in one embodiment can be a serial communication bus, but could be of any of a number of well known designs, e.g., a parallel bus, Ethernet Local Area Network (LAN), etc. Optionally, bus 54 can provide communication with the Internet 52 using a number of well known protocols.

15       Importantly, bus 54 is also coupled to a cradle 60 for receiving and initiating communication with a palm top ("palm-sized") portable computer system 100 of the present invention. Cradle 60 provides an electrical and mechanical communication interface between bus 54 (and anything coupled to bus 54) and  
20 the computer system 100 for two way communications. Computer system 100 also contains various wireless communication mechanisms 64 for sending and receiving information from other devices, specifically a wireless modem 240 (Figure 3) can be used to communicate with the Internet 52.

Figure 6 is a perspective illustration of one embodiment of the cradle 60 for receiving the palmtop computer system 100. Cradle 60 contains a mechanical and electrical interface 260 for interfacing with serial connection 108 (Figure 2B) of computer system 100 when system 100 is slid into the cradle 60 in an upright position. Once inserted, button 270 can be pressed to initiate two way communication between system 100 and other computer systems coupled to serial communication 265.

CONTROLLABLE PIXEL BORDER OF THE PRESENT INVENTION

FOR A PASSIVE MATRIX DISPLAY USING NEGATIVE MODE DISPLAY

Figure 7 illustrates a front view of the display screen in accordance with an embodiment of the present invention. The display screen 310 contains two different display regions. Region 314 is the frame buffer pixel region and contains a matrix of discrete pixels (color or black and white) oriented in n rows and m columns according to a variety of display dimensions and formats. Region 314 generates an image that is a representation of data stored in a frame buffer memory (also called video memory) of computer system 100. Although region 314 can have any dimension, in one embodiment it includes the dimensions of 160 pixels by 160 pixels. The computer system, e.g., the operating system, controls the information that is stored into the frame buffer memory and thereby controls the pixels of region 314. In one embodiment of the present invention, the frame buffer region 314 is implemented with passive display technology, e.g., passive matrix liquid crystal display (LCD) technology. However, any number of well known passive matrix technologies could also be used, such as, electronic paper, electronic ink and microelectromechanical systems (MEMS).

In one embodiment, the passive matrix technology used is negative mode display supertwisted nematic LCD technology. In negative mode display, the pixels are naturally black when in the off state and are bright when turned on.

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Surrounding region 314 of Figure 7 is a novel pixel border region 312 in accordance with the present invention and having a predetermined pixel width, x. The pixels of the pixel border region 312 are not independently addressable, like the pixels of the frame buffer region 314, but are rather uniformly controllable

10 between an on state and an off state by a single control signal that is under processor control. Although the width, x, of the pixel border region 312 is arbitrary, in one embodiment the width is two pixels. The pixel border region 312 of the present invention is not controlled by the frame buffer memory, but rather by the single control signal discussed above. Like the frame buffer region 314, the  
15 pixel border region 312 is also implemented using a negative mode display passive matrix display technology.

The pixel border region 312 is useful for giving contrast improvement for the viewability of edge located characters. In one implementation, the present  
20 invention uses negative mode display LCD in which the pixels are naturally black. Using this technology, in one display format, the background pixels are driven to be bright or white, while the foreground pixels (e.g., those that make up the characters in a text display) are darker or black. In this mode, the pixels of the pixel border 312 are generally displayed white to match the background pixel  
25 color. Specifically, the pixel border 312 is useful for giving contrast improvement

for characters displayed along the edges, e.g., upper, lower, right and left, of region 314 (see Figure 14). The total viewing area (in pixels) of the display screen when  $x=2$  is therefore  $n+4$  rows and  $m+4$  columns.

5       Figure 8 illustrates a logical diagram of the components of the novel display unit 105 in accordance with an embodiment of the present invention. Frame buffer memory 320 contains a bitmapped image for display. This frame buffer is read, periodically, by a display controller 322. The display controller 322 is well known. Display controller 322 is either coupled directly to a display driver  
10      326 or to a timing generator 324. Controller 322 generates well known timing signals, such as vertical and horizontal synchronization signals, as well as clocking signals; all required to properly propagate image data into the display drivers 326. The timing generator 324 is sometimes needed to convert the signals from the controller according to the requirements of the drivers.  
15  
It is appreciated that if drivers are available to drive a matrix larger in size than the frame buffer region, then in this alternative case, the conventional drivers may be used to drive the pixels of the border region in accordance with the present invention. In this particular embodiment, the timing generator will supply  
20      the border data to the border pixels.

The display drivers 326 are coupled to the pixels within the display matrix 310. The display matrix 310 generates images by the modulation of light by discrete pixel elements. The display matrix 310 can be a passive matrix liquid

crystal display (LCD) technology but could also be of any passive display technology, as described above.

Figure 8 also illustrates the single control signal 895 that is under  
5 processor control. This signal indicates the display mode of the pixel border  
region 312. If this signal 895 is asserted, then all the pixels of the border 312  
are uniformly turned on, e.g., remain white or bright until this signal changes. If  
this signal 895 is not asserted, then all the pixels of the border 312 are uniformly  
turned off, e.g., remain black or dark until this signal changes. In normal display  
10 operations, when the background pixels are white and the foreground pixels are  
dark, e.g., reverse video, then the border pixels are turned on to provide contrast  
for edge displayed characters when using negative mode display LCD.

Figure 9 illustrates one implementation of the circuitry of the display drivers  
15 326 and the display matrix 310 (of Figure 8). In this example,  $x=2$ , but could be  
any width in accordance with the present invention. There are  $n$  row drivers  
420a-420e and  $m$  column drivers 410a-410d which make up the frame buffer  
region 314. In color implementations, three subpixels, red, green, and blue, are  
required to form a single pixel and therefore  $3m$  column drivers are required.  
20 Each column driver and each row driver is coupled to a respective column line  
and a respective row line. 2x Row drivers 450a-450d and 2x column drivers  
440a-440d are used for the pixels of the border region 312.

In passive LCD technology, the pixels comprise the intersection of one row  
25 line and one column line, e.g., the intersection of two electrodes, and typically

does not include any active element. An exemplary pixel 460b of the matrix region 314 is shown and an exemplary pixel 460a of the border region 312 is shown. Pixel 460b is shown in more detail in Figure 10 for the color implementation and is comprised of three RGB subpixels 460(1)-460(3). Three 5 column drivers 410b\_r, 410b\_g and 410b\_b are used in the color implementation.

Driving signals are synchronized to meet, in time, at the intersection of a row and a column line to activate the respective pixel with a localized electric field, as is well known, to switch the pixel. The rows 420 of the frame buffer matrix 314 are scanned sequentially (according to synchronized row driver 422) from row 1 to row n to display a frame within region 314. Frames are generated from 10 30-50 Hz. For each row on-time, associated column data is shifted into the column drivers 410 by a column loader 412. In one example, the row on-time signal may be a square pulse for each column of data, from column 1 to column 15 m. The column line then has its own pulse which depends on the gray scale of the pixel. However, the present invention may operate with any of the well known passive matrix driving schemes.

20 According to Figure 9, the row and column drivers used for the pixel border do not sequentially scan in one embodiment. In the embodiment discussed above where conventional drivers are available to drive the border pixels, then in this case, row and column drivers used for the pixel border could sequentially scan. The 2x row drivers 450a-450d of the pixel border region 312 are coupled 25 to a threshold voltage driver 430b which provides a constant common voltage

level ( $V_{th2}$ ) when in the on state. Likewise, the 2x column drivers 410a-410d of the pixel border region 312 are coupled to a threshold voltage driver 430a which provides a constant common voltage level ( $V_{th1}$ ) when in the on state. The difference between these threshold voltage levels comprises a threshold voltage 5 ( $V_2$ ). The voltage  $V_2$ , or a greater amount, is common to and applied to all pixels of the border region 312 uniformly when in the on state. The difference between these threshold voltage levels comprises a threshold voltage ( $V_1$ ). The voltage  $V_1$ , or less, is common to and applied to all pixels of the border region 312 uniformly when in the OFF state.

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As shown by the voltage transfer curve 810 for the negative mode display supertwisted nematic LCD of Figure 11, the threshold voltage,  $V_1$ , achieves 10 percent white or less, which is considered black. The threshold voltage,  $V_2$ , achieves 90 percent white or more, which is considered white. It is appreciated 15 that the 10 percent or the 90 percent values used above are exemplary only and can be adjusted based on user preference.

The threshold driver circuits 430a and 430b of Figure 9 are enabled via a switch circuit 430c which receives a signal control signal 895. When enabled, the 20 constant voltage  $V_2$  is applied to the pixels of the pixel border region 312 and the pixel border 312 becomes white. When not enabled, no voltage, or a voltage of less than  $V_1$  is applied to the pixels of the pixel border region 312 and the pixel border 312 becomes dark. Signal 895 is processor controlled and can be made available to the operating system of computer 100.

Figure 12 illustrates a block diagram of display circuit 600 which includes the column drivers 410 and 440 and row drivers 420 and 450 which drive the passive matrix 310. Also shown, are the threshold voltage drivers 430a and 5 430b. As shown in Figure 12, a gray scale bias voltage circuit 610 is used to control the generation of the threshold voltages which are used to provide the different gray scales used by the pixels in the frame buffer memory 312. In one embodiment, a resistor ladder circuit can be used as circuit 610 to generate the threshold voltages. Importantly, a contrast adjustment circuit 620 varies the bias 10 voltage applied to circuit 610 thereby providing a mechanism for uniformly adjusting the gray scale voltages produced by circuit 610 to thereby adjust the contrast of region 314.

Advantageously, circuit 610 of Figure 12 also generates a threshold 15 voltage that is supplied to driver circuits 430a and 430b. The threshold voltage supplied to driver circuits 430a-430b varies based on the contrast adjustment and effects the values of V1 and V2 that are applied to the pixels of the border region 312. In this case, any variation in the contrast of region 314 can be matched by a corresponding and like variation in the contrast of region 312. Therefore, the 20 contrast of regions 314 and 312 will be matched in response to any contrast variation by circuit 620. It is appreciated that contrast adjustment circuit 620 can include a manual adjustment that is user controlled or it can include an automatic adjustment that is based on environmental conditions, such as temperature, ambient lighting, etc.

Figure 13A illustrates a cross section of a transflective or transmissive display matrix 310 in accordance with one embodiment of the present invention. In this embodiment, a backlighting element 570, e.g., a cold cathode fluorescent (CCF) tube or other lighting device, is illustrated adjacent to a rear polarizer layer 560. A passive matrix LCD layer 530 is also shown. The passive matrix layer 530 maps to region 314 and may control n rows and m columns of pixels. Region 540 and region 550 correspond to the pixel border 312. An optional color filter pattern 520 is also shown. After the color filter pattern 520, a front polarizer layer 10 510 is provided.

Figure 13B illustrates a cross section of a reflective display matrix 710 in accordance with one embodiment of the present invention. In this embodiment, a reflective passive matrix LCD layer 725 is used. Layer 725 maps to region 314 and may control n rows and m columns of pixels. Region 740 and region 745 correspond to the pixel border 312. An optional frontlight layer 750 can be used and a front polarizer 510 is shown along with a rear reflector 760. The color filter pattern 720 can be used.

20 Figure 14 illustrates a resultant display in accordance with the present invention using a pixel border of width  $x = 2$ . The pixels 380 of the edge displayed character, "A," are dark and the background pixels are white in this case, e.g., one exemplary form of a reverse video display format. The display is negative mode LCD. The edge region 28 of the display panel is dark, e.g., the 25 same or similar color as the pixels 380 of the character. In this exemplary case,

the border pixels 312 of the present invention are driven white. The total number of pixels in the display 310 are  $(m+2x)$  by  $(n+2x)$ .

By providing a white border region 312, the contrast along the left edge of  
5 the character, "A," is much improved thereby improving viewability of the  
character. This advantageous result is achieved without any requirement of  
changing the operating system of the computer because the standard  $(m \times n)$   
pixel region 314 of the display remains unchanged. Furthermore, because the  
border pixels of region 312 have their own special driver circuitry, standard  $(m \times$   
10  $n)$  driver circuits and software can be used with the present invention to generate  
images within region 314.

The preferred embodiment of the present invention, a controllable pixel  
border for a negative display mode passive matrix display screen which provides  
15 contrast improvement for increased viewability of edge-displayed characters, is  
thus described. While the present invention has been described in particular  
embodiments, it should be appreciated that the present invention should not be  
construed as limited by such embodiments, but rather construed according to the  
below claims.